

1.0 INTRODUCTION

This report presents the Feasibility Study (FS) for the Portland Harbor Superfund Site in Portland, Oregon (Figure 1-1). Portland Harbor was evaluated and proposed for inclusion on the National Priorities List (NPL) pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), 42 U.S.C. §9605, by the U.S. Environmental Protection Agency (EPA) and formally listed as a Superfund Site in December 2000. The lead agency for this site is EPA.

The basis of this FS is environmental data collected and compiled by the Lower Willamette Group (LWG) and other sources since the inception of the Portland Harbor Remedial Investigation and Feasibility Study (RI/FS) in 2001¹. The LWG is performing the remedial investigation (RI) and FS for the Portland Harbor Superfund Site (Site) pursuant to an EPA Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (AOC; EPA 2001, 2003, 2006). Oversight of LWG's Portland Harbor RI and FS is being provided by EPA with support from Oregon Department of Environmental Quality (DEQ).

The RI (insert citation) has been completed and has characterized the Site sufficiently to define the nature and extent of the source material and the Site-related contaminants. Baseline ecological and human health risk assessments (Windward 2013; Kennedy Jenks 2013) have also been completed. The site characterization and baseline risk assessments are sufficient to complete the FS for the Site.

This FS focuses on ten miles of the lower Willamette River from RM 1.9 (at the upriver end of the Port of Portland's Terminal 5) to RM 11.8 (near the Broadway Bridge), sometimes referred to as the "site" in this FS for convenience. The terms site, harbor-wide, and site-wide used in this FS generally refer to the sediments, pore water, and surface water within this reach of the lower Willamette River, not to the upland portions of the Portland Harbor Superfund Site.

This FS is consistent with CERCLA, as amended (42 United States Code [U.S.C.] 9601 et seq.), and its regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] Part 300), commonly referred to as the National Contingency Plan (NCP) and was prepared in accordance with EPA guidance. Guidance documents used in preparing this FS include:

- *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988)

¹ Upland source control efforts, including site-specific upland source control studies and implementation of source control measures, are performed under the oversight of the Oregon Department of Environmental Quality and are not within the scope of the Agreement and Order on Consent and Statement of Work for the in-water portion of the Site.

- *Clarification of the Role of Applicable or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA* (EPA 1997a)
- *Rules of Thumb for Superfund Remedy Selection* (EPA 1997b)
- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA 2002)
- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005)
- *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000).

1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of the FS is to identify, develop, screen, and evaluate a range of remedial alternatives for the contaminated media and to provide the regulatory agencies with sufficient information to select a remedy that meets the requirements established in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This FS report is comprised of four sections as described below.

- Section 1 – Introduction, provides a summary of the Site RI, including Site description, Site history, nature and extent of contamination, contaminant fate and transport, and baseline human health and ecological risks.
- Section 2 - Identification and Screening of Technologies, develops remedial action objectives (RAOs), develops preliminary remediation goals (PRGs) for addressing human health and ecological risks posed by contaminants in sediment and tissue, develops general response actions (GRAs) for each medium of interest, identifies areas of media to which general response actions might be applied, identifies and screens remedial technologies and process options, and identifies and evaluates technology process options to select a representative process for each technology type retained for consideration.
- Section 3 - Development and Screening of Alternatives presents a range of remedial alternatives developed by combining the feasible technologies and process options. The alternatives are then refined and screened to reduce the number of alternatives that will be analyzed in detail. This screening aids in streamlining the feasibility study process while ensuring that the most promising alternatives are being considered.
- Section 4 - Detailed Analysis of Alternatives provides the detailed analysis of each alternative with respect to the following seven criteria: 1) overall protection of human health and the environment, 2) compliance with ARARs, 3) long-term

effectiveness and permanence, 4) reduction of toxicity, mobility, or volume through treatment, 5) short-term effectiveness, 6) implementability, and 7) cost. In addition to the detailed analysis, a comparative analysis of remedial action alternatives is also presented in this section. EPA also recognizes that this site affects many stakeholders, including environmental justice communities along the river, and the evaluation of remedial alternatives will consider impacts to these communities.

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 miles north to its confluence with the Columbia River, and is one of 14 American Heritage Rivers in the country. It is the 12th largest river in the United States, and drains 11.7 percent of the State of Oregon. As Oregon's major port and population center, the lower Willamette River sees a great variety of uses ranging from shipping, industrial, fishing, recreational, natural resource, and other uses. The lower reach of the Willamette River from River Mile (RM) 0 to approximately RM 26.5 is a wide, shallow, slow moving segment that is tidally influenced with tidal reversals occurring during low flow periods as far upstream as RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the lower Willamette River system. The lower reach has been extensively dredged to maintain a 40-foot deep navigation channel from RM 0 to RM 11.6.

The Portland Harbor RI/FS Study Area is located along an 11.6-mile dredged reach of the Lower Willamette River in Portland, Oregon known as Portland Harbor (**Figure 1-1** and **Figures 1.11-2a through 1.11-2d**). While the harbor area is extensively industrialized, it occurs within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the lower Willamette River in the harbor includes marine terminals, manufacturing, and other commercial operations, as well as public facilities, parks, and open spaces. **Figures 1.2-1a through 1.2-1d** illustrate land use zoning within the lower Willamette River as well as waterfront land ownership.

1.2.2 Site History

Since the late 1800s, the Portland Harbor section of the Lower Willamette River has been extensively modified to accommodate a vigorous shipping industry. Modifications include redirection and channelization of the main river, draining seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Constructed structures, such as wharfs, piers, floating docks, and pilings, are especially common in Portland Harbor where urbanization and industrialization are most prevalent. These structures are built largely to accommodate or support shipping traffic within the river and to stabilize the

riverbanks for urban development. Riprap is the most common bank-stabilization measure. However, upland bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to control periodic flooding as most of the original wetlands bordering the Willamette in the Portland Harbor area have been filled. Constructed structures are clearly visible in the aerial photos provided in **Figures 1.2-2a through 1.2-2n**.

Today, the Willamette River is noticeably different from the river prior to industrial development that commenced in the mid to late 18th century. Historically, the Willamette was wider, had more sand bars and shoals, and fluctuated greatly in volume. In contrast, the main river now has been redirected and channelized, several lakes and wetlands in the lower floodplain have been filled and agricultural lands converted to urban or industrial areas. The end result is a river that is deeper and narrower than it was historically with higher banks that prevent the river from expanding during high-flow events. The Willamette River channel, from the Broadway Bridge (RM 11.6) to the mouth (RM 0), currently varies in width from 600 to 1,900 feet. Further, the installation of a series of dams moderate fluctuations of flow in the lower Willamette River. Little, if any, original shoreline or river bottom exists that has not been modified by the above actions, or as a result of them. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes.

A federal navigation channel, with an authorized depth of -40 feet, extends from the confluence of the lower Willamette River with the Columbia River to RM 11.6. The lower Willamette River federal navigation project was first authorized in 1878 to deepen and maintain parts of the Columbia River and lower Willamette River with a 20-foot minimum depth. The depth of the navigation channel has been deepened at various intervals since that time (i.e., increased to 25 feet in 1899, 30 feet in 1912, 35 feet in 1930, and 40 feet in 1962). Container and other commercial vessels regularly transit the river. Certain parts of the river require periodic maintenance dredging to keep the navigation channel at its authorized depth. In addition, the Port of Portland and other private entities periodically perform maintenance dredging to support access to dock and wharf facilities. Dredging activity has greatly altered the physical and ecological environment of the river in Portland Harbor.

Development of the river has resulted in major modifications to the ecological function of the lower Willamette River. However, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that occur within and along the river. The river is also an important rearing site and pathway for migration of anadromous fishes, such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, are active within the lower Willamette River. A detailed description of ecological communities in Portland Harbor is presented in the Baseline Ecological Risk Assessment (BERA) provided as Appendix G of the RI Report.

The lower Willamette River and its adjacent upland areas have been used for industrial, commercial, and shipping operations for over a century. Commercial and industrial development in Portland Harbor accelerated in the 1920s and again during World War II, which reinvigorated industry following the Great Depression. Before World War II, industrial development primarily included sawmills, manufactured gas production (MGP), bulk fuel terminals, and smaller industrial facilities. During World War II, a considerable number of ships were built at military shipyards located in Portland Harbor. Additional industrial operations located along the river in the post-World War II years included wood-treatment, agricultural chemical production, battery processing, ship loading and unloading, ship maintenance, repair and dismantling, chemical manufacturing and distribution, metal recycling, steel mills, smelters, and foundries, electrical production, marine shipping and associated operations, rail yards, and rail car manufacturing. Many of these operations continue today. Contaminants associated with these operations were released from various sources and migrated to the lower Willamette River. The long history of industrial and shipping activities in the Portland Harbor, as well as agricultural, industrial, and municipal activities upstream of Portland Harbor, has contributed to chemical contamination of surface water and sediments in the Lower Willamette River. Detailed information regarding historic and current sources of contamination in the lower Willamette River is provided in Section 4 of the RI Report.

Historical and current locations of various industrial facilities identified along the lower Willamette River are provided by industrial sector in **Figures 1.2-3a** through **1.2-3j**. The approximate location of facilities is shown on the maps; however, the actual extent of historical and current facilities/operations is not shown.

Each of these industrial sectors is typically associated with the use of various chemicals. The contaminants most commonly associated with each industry sector include the following:

| Industrial Sector | Common Industry Contaminants |
|--|---|
| Ship Building, Dismantling, and Repair | Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), metals, phthalates, butyltins |
| Wood Products and Wood Treating | VOCs, SVOCs, TPH (oil, grease, diesel, gasoline), benzene, PAHs, metals, wood preservatives (arsenic compounds, copper compounds, chromium compounds, pesticides, fungicides, biocides, borates, pentachlorophenol, creosote), acid/alkaline wastes, PCBs, dioxins/furans |

| Industrial Sector | Common Industry Contaminants |
|--|--|
| Chemical Manufacturing and Distribution | Vary depending on the operations, but chemical manufacturing known to have occurred within Portland Harbor, includes pesticides, herbicides, VOCs, SVOCs, dioxins/furans, metals, PCBs, solvents, acid/alkaline wastes, benzene, TPH (oil, grease, diesel, gasoline), and PAHs |
| Metal Recycling, Production, and Fabrication | VOCs, SVOCs, TPH, PCBs, metals, infectious/bacterial contamination, asbestos, cyanide, phthalates, fuel additives, and products of incomplete combustion, battery acid |
| Manufactured Gas Production | VOCs including benzene, toluene, ethylbenzene, and xylenes (BTEX), SVOCs, PAHs, TPH, metals, and cyanide |
| Electrical Production and Distribution | PCBs, TPH, and PAHs |
| Bulk Fuel Distribution and Storage, and Asphalt Manufacturing | VOCs (benzene), SVOCs, PAHs, TPH (oil, gas and diesel fuels), metals, gasoline additives (methyl tert-butyl ether [MTBE], ethylene dibromide [EDB], ethylene dichloride [EDC]) |
| Steel Mills, Smelters, and Foundries | Metals, TPH (from oil, gas, and diesel fuels), PAHs, PCBs, fuel additives, chlorinated solvents (VOCs) |
| Commodities Maritime Shipping and Associated Marine Operations | Spillage of raw materials during transport to and from vessels, butyltins, metals, TPH (gasoline, diesel, oil, lubricants and grease), fuel additives, chlorinated solvents (VOCs) |
| Rail Yards | VOCs, SVOCs, TPH, PCBs, and metals |

Contaminants released during industry operations and/or other activities to the air, soil, groundwater, surface water, and/or impervious surfaces can potentially migrate to the lower Willamette River via the following pathways: direct discharge, overland transport, groundwater, riverbank erosion, atmospheric deposition, overwater activities, and upstream watershed.

One key migration pathway for contaminants from these various industries to migrate to the river was through direct discharge via numerous municipal and private outfalls, including storm drains and combined sewer overflows, which were and are located along both shores of the lower Willamette River in the metropolitan area. In the early 1900s, rivers in the United States were generally used as open sewers, which was also true for the Willamette (Carter 2006). The growing city's untreated sewage, as well as process water from a variety of industries, including slaughterhouses, chemical plants, electroplaters, paper mills, and food processors, was discharged directly into the river. The City of Portland constructed a wastewater treatment plant in the early 1950s and

regulatory actions in the 1960s and 1970s, such as the Clean Water Act, gradually reduced the direct discharge of waste to the Willamette River.

Historical releases from upland or overwater activities within the Study Area likely contributed to the majority of the observed contaminant distribution in sediments within the Study Area. The majority of current contaminant pathways to the river (soil, groundwater, and stormwater) from upland sources are a result of historical operational practices, spills, and other releases.

In addition, point and nonpoint discharges within the Willamette River Basin are potential sources of contamination in sediment, surface water, and biota in the Study Area. Contaminants in discharges and runoff from diverse land uses in the basin eventually enter the river upstream of the Study Area. Contaminant loading from sediment transport and water from upstream areas throughout the last century may also contributed to the conditions currently observed in the Study Area.

1.2.2.1 Investigation History

Many environmental investigations by private, state, and federal agencies have been conducted, both in the lower Willamette River and on adjacent upland properties, to characterize the nature and extent of contamination in the river, as well as to identify potential sources of contaminants that could continue to enter the river. Investigations have been conducted in Portland Harbor from the 1920s to the present, with most studies being performed from the late 1970s through the 1990s. Nearly 700 documents and data sets were obtained that address conditions in the lower Willamette River. Specific historical and recent studies and data sets were selected for inclusion in the data set used to characterize and evaluate the Study Area in the RI report. Section 2 of the RI discusses and identifies the specific non-LWG collected data that were included in the RI data set.

Site data were collected by the LWG during four major rounds of field investigations between 2001 and 2008 to complete the RI. The investigations were often timed around varying river stages, river flows, and storm events. The field investigations first began in 2001 in the Initial Study Area (ISA) as defined by the AOC, SOW, and Programmatic Work Plan as RM 3 to RM 9. As the studies commenced, the Study Area was expanded from RM 1.9 to RM 11.8, and included a portion of Multnomah Channel. Additional studies were conducted by specific parties at several sites within the Study Area with EPA oversight include offshore areas of Arkema, Gasco (NW Natural), Siltronic, Terminal 4, and River Mile 11 East. The data generated from these investigations were included in the RI and FS data sets. Studies conducted by the LWG also included areas downriver of the Study Area to the confluence with the Columbia River at RM 0 and upriver to RM 28.4. Surface and subsurface sediment samples, sediment trap samples, riverbank sediment and soil samples, surface water samples, stormwater and stormwater solids samples, groundwater samples, transition zone water (TZW) samples, and biota/tissue samples were collected and analyzed during the various investigations.

1.2.2.2 Upland Source Control Measures

Identifying current sources of contamination to the Study Area and eliminating or minimizing these pathways where possible is critical for remedy effectiveness as well as evaluating the recontamination potential of a cleanup. In February 2001, DEQ, EPA, and other governmental parties signed a Memorandum of Understanding (MOU) agreeing that DEQ, using state cleanup authority, has lead technical and legal responsibility for identifying and controlling upland sources of contamination that may impact the river (e.g., sediment, groundwater, transition zone water, and/or surface water). Currently, DEQ is investigating or directing source control work at over 90 upland sites in Portland Harbor and evaluating investigation and remediation information at more than 80 other upland sites in the vicinity. Additionally, DEQ is working with the City of Portland under an Intergovernmental Agreement to identify and control upland sources draining to the Study Area through 39 city outfalls, and with the Oregon Department of Transportation on controlling sources in highway and bridge runoff drained to the Study Area.

In 1994, the City prepared a CSO Management Plan with recommendations to address wet weather overflow discharges, including implementation of storage and treatment facilities along the Willamette River (“Big Pipe project”) to control the CSO discharges. The primary means for increasing the storage capacity was through construction of the West Side Tunnel (completed in 2006) and the East Side Tunnel (completed in 2011).

The cleanup of known or potentially contaminated upland sites is tracked in DEQ’s Environmental Cleanup Site Information (ECSI) database, which is available online at <http://www.deq.state.or.us/lq/ECSI/ecsi.htm>, and source control efforts are summarized in DEQ’s Portland Harbor Upland Source Control Summary Report (<http://www.deq.state.or.us/lq/cu/nwr/PortlandHarbor/jointsource.htm>).

Figures 1.2-4a through 1.2-4e graphically display the status of DEQ source control evaluations as of 2011 for various sites along the Study Area by potential release/migration pathways to the river.

1.2.2.3 Early Action Sites

Within Portland Harbor, separate removal orders have been executed by EPA various parties for five specific sites. These sites are:

1. Terminal 4 – conducted by the Port of Portland
2. Gasco Phase I – conducted by NW Natural
3. Gasco and Siltronic – conducted by NW Natural and Siltronic
4. Arkema – conducted by Arkema

5. RM 11 E – conducted by Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland.

These projects are currently in various stages of completion as described below. Information from these early action sites has been included in the Portland Harbor FS for use in the development and detailed evaluation of alternatives.

- **Terminal 4** – The Port of Portland has been implementing a removal action at Terminal 4. A Phase I Abatement Measure was completed in 2008 that consisted of remediation and maintenance dredging of approximately 13,000 cubic yards of sediment. Remediation consisted of dredging 6,315 cubic yards of contaminated sediment and placing it in an off-site disposal facility, isolating contaminated sediment in the back of Slip 3 with a cap made of organoclay-sand mix, and stabilizing the bank along Wheeler Bay. The post-construction sediment data collected in this area was included in the FS database and this area will be evaluated in this FS to determine if further action is needed.
- **Gasco (NW Natural) Phase I** – A removal action was conducted at the Gasco site between August and October 2005. Approximately 15,300 cubic yards of a tar-like material and tar-like contaminated sediment were removed by dredging from the riverbank and nearshore area adjacent to the Gasco facility and disposed of off-site. After the removal action, an organoclay mat was placed along an upper-elevation band of the shoreline dredge cut. This mat was secured with placement of an overlying sand cap and quarry spalls. A 1 foot thick sand cap and 0.5 foot of erosion protection gravel was placed over the remainder of the removal area (0.4 acres). Approximately 0.5 foot of a “fringe cap” of sand material was placed over 2.3 acres of the area surrounding the removal area.
- **Gasco (NW Natural) and Siltronic** – NW Natural and Siltronic are conducting site characterization and preliminary design evaluations for the area adjacent to their two facilities. Data collected as part of this effort has been incorporated within the harbor-wide FS database for use in developing and evaluating alternatives. Under the order, NW Natural and Siltronic have agreed to perform remedial design of the remedy selected in the Record of Decision (ROD). The remedial action for the NW Natural and Siltronic sediments following completion of any necessary upland NW Natural and Siltronic source control work being managed by DEQ.
- **Arkema** – Under an AOC with EPA, Arkema conducted additional site characterization and preliminary design evaluations for a planned Removal Action. Data collected as part of this effort have been incorporated into the harbor-wide FS database for use in developing and evaluating alternatives. Areas within and around the Arkema Removal Action Area. Although EPA and

Arkema suspended the AOC in 2014, work on the EE/CA has continued with the intent for it to facilitate remedial design for the site subsequent to the ROD.

- **River Mile 11 East** - A group of Respondents, collectively known as the RM11E Group (includes Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland), entered into an AOC to perform supplemental remedial investigation and feasibility study work in support of preliminary design activities. Work completed in 2013/2014 within the RM11E Project Area included shallow sediment sampling, riverbank sampling, and upland groundwater monitoring well installation and sampling. Porewater sampler deployment is scheduled for August-October 2014.

In addition, a near-shore sediment removal adjacent to the BP Arco Bulk Terminal in 2007-08 under DEQ oversight resulted in 12,300 cubic yards of petroleum-contaminated soil and sediment being removed and disposed of off-site, and replaced with clean fill in conjunction with the installation of a new steel sheet-pile seawall along the entire riverbank.

1.2.3 Nature and Extent of Contamination

Due to the large number of contaminants detected at the site in various media, the nature and extent of contamination focused on specific contaminants or groups of contaminants selected by evaluating several criteria discussed in Section 5.1 of the RI. The following contaminants were selected for evaluation in the RI:

- Total polychlorinated biphenyls (PCBs)
- Total Polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs)
- Total PAHs
- Total carcinogenic PAHs (cPAHs)
- Total low molecular weight PAHs (LPAHs)
- Total high molecular weight PAHs (HPAHs)
- Benzo(a)pyrene
- Naphthalene
- Phenanthrene
- Total DDx
- Aldrin
- Dieldrin
- Chlordanes
- gamma-Hexachlorocyclohexane (Lindane)
- Tributyltin ion
- Arsenic
- Cadmium
- Chromium
- Copper

- Lead
- Mercury
- Nickel
- Zinc
- TPH
- Diesel-range hydrocarbons
- Residual-range hydrocarbons
- Bis(2-ethylhexyl) phthalate
- Butylbenzyl phthalate
- Pentachlorophenol
- Hexachlorobenzene

This list was further reduced in Section 5 of the RI to 14 indicator contaminants in sediment based frequency of detection, ease of cross media comparisons, co-location with other contaminants, widespread sources, and similar chemical structures and properties. Information regarding additional contaminants in sediment, surface water, and groundwater is provided in Appendix D of the RI. The nature and extent of indicator contaminants in sediment, surface water, and river banks are summarized in the following sections. Nature and extent of contaminated groundwater plumes is also discussed below; however, the contaminants in groundwater differ from the indicator contaminant list for sediment.

1.2.3.1 Sediment

Sediment samples were collected throughout the Study Area from 2002 to 2013. Sample locations were biased toward areas of known or suspected contamination based on existing information, with additional sampling upstream and downstream of the Study Area. Summary statistics of surface sediment results for the contaminants presented above are provided in **Table 1.2-1**. A summary of the 14 indicator contaminants presented in the RI is presented below.

PCBs

With few exceptions, the highest PCB concentrations in surface sediment are present in nearshore areas outside the navigation channel and proximal to currently known or suspected sources (**Figure 1.2-5**). Similar spatial and concentration trends are observed for subsurface sediments. Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical. Overall, surface sediment PCB concentrations in the Study Area are significantly greater than those in the upriver (upstream of Ross Island) and downstream (mainstem of the lower Willamette River downstream of RM 1.9 and Multnomah Channel) reaches.

Dioxins/Furans

Total PCDD/Fs were detected several locations along the eastern and western nearshore zones and in Swan Island Lagoon (**Figure 1.2-6**). Limited surface PCDD/F data are available for the navigation channel and spatial resolution is somewhat limited. Total PCDD/F concentrations in the subsurface are generally greater than that observed in surface sediments. The higher concentrations generally observed in subsurface sediment relative to concentrations in surface sediment are indicative of a primarily historical input of these contaminants to the Study Area.

DDx

The highest reported DDx concentrations in surface sediments are present in localized areas in the western nearshore zones between RMs 6 and 7.5 (**Figure 1.2-7**). DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical. The concentrations of DDx in surface sediments are greater in the Study Area than those in the upriver, downtown, Multnomah Channel, and downstream reaches.

PAHs

The highest reported concentrations of total PAH in surface sediments generally occur in the western nearshore zone downstream of RM 7, and on the east side at approximately RM 4.5 (**Figure 1.2-8**). Total PAH concentrations are generally higher in subsurface sediments within the Site as a whole, pointing to higher historical inputs to the Site. Within the Study Area, total PAHs in sediment are generally dominated by HPAHs. Surface sediments from the western nearshore zone appeared to exhibit higher proportions of LPAHs than sediments from the eastern nearshore zone and the navigation channel, but follow the general trend of HPAH dominance. Subsurface generally exhibit similar PAH profiles to the surface sediments.

Bis(2-ethylhexyl) phthalate

The highest reported concentrations of bis(2-ethylhexyl) phthalate were observed in samples collected in surface sediment from the eastern nearshore in Swan Island Lagoon, and between RM 3.8 and 4.1 in the International Terminals Slip (**Figure 1.2-9**).

Chlordanes

The highest reported concentrations of chlordanes were observed along the western nearshore zone between approximately RM 6 and 7.4 (**Figure 1.2-10**). Total chlordane concentrations are generally higher in subsurface sediments within the Site, pointing to higher historical inputs to the Site.

Lindane

Detected concentrations of gamma-hexachlorocyclohexane (Lindane) were generally lower within the navigation channel (**Figure 1.2-11**). The highest reported sediment concentrations were reported from samples along the western nearshore zone between approximately RM 6 and 7.4.

Aldrin and Dieldrin

Aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin quickly breaks down into dieldrin in the environment. The highest reported concentrations were observed in the western nearshore zone around RM 7.4 and the western nearshore zone at RM 8.8 (**Figures 1.2-12 and 1.2-13**). Aldrin concentrations are higher in subsurface sediments than surface sediments within the Site, pointing to higher historical inputs to the Study Area.

Metals

The highest reported arsenic concentrations were reported in several locations in the eastern nearshore at RM 2.3, RM 5.7, RM 7, near the mouth of Swan Island Lagoon, and in the western nearshore area of RM 9 to RM 10.3 (**Figure 2.1-14**).

The highest reported chromium concentrations were observed in the eastern nearshore zone in RM 2, RM 4, RM 5, and in Swan Island Lagoon, and in the western nearshore zone in RM 6 and RM 9 (**Figure 2.1-15**).

Copper concentrations are generally higher in subsurface sediments than surface sediments within the Site, pointing to higher historical inputs to the Study Area (**Figure 2.1-16**).

The highest surface and subsurface sediment zinc concentrations were found between RM 8.2 and 9.2 (**Figure 2.1-17**).

Tributyltin Ion

The highest concentrations of tributyltin were reported in surface sediment near the eastern nearshore zone between RM 8 and RM 9 and near the entrance to the International Terminals Slip near RM 3.7 (**Figure 2.1-18**). Concentrations are generally higher in subsurface sediments than surface sediments within the Site, pointing to primarily historical inputs to the Study Area.

1.2.3.2 Surface Water

Concentrations of contaminants in surface water samples varied both spatially and with river flow. Surface water sample locations with the highest reported contaminant concentrations are as follows:

| River Mile | River Location | Sample ID | Contaminants |
|------------|--------------------|------------------|--|
| MC | Transect | W027 | PCDD/Fs, aldrin, copper |
| 2 | East | W001 | PCBs, DDx |
| | West | W002 | chlordanes |
| | Transect | W025 | PCBs, BEHP, aldrin |
| 3 | International Slip | W004 | PCBs |
| | East | W028 | PCBs |
| 4 | West | W029 | BEHP, chlordanes |
| 5 | East | W030 | PCBs, DDx, chlordanes |
| 6 | East | W013, W014, W032 | PCBs, PCDD/Fs |
| | West | W015, W031 | PCBS, PCDD/Fs, DDx, PAHs, chlordanes, aldrin, dieldrin, copper |
| | Transect | W011 | PCDD/Fs, BEHP, aldrin |
| 7 | West | W016, W033 | PCBs, PCDD/Fs, DDx |
| 8 | West | W019, W036 | PCBs, PAHs, BEHP |
| 9 | West | W022, W037 | DDx, zinc |
| 11 | Transect | W023 | PCDD/Fs, chlordanes, copper |
| 16 | Transect | W024 | BEHP, copper |

RM 7E was not sampled.
RM 8E was not sampled.
RM 9E was not sampled.
RM 10 was not sampled.

Locations where surface sample results exceed ambient water quality criteria are presented on Figure 1.2-19. Concentrations of contaminants in surface water within the Study Area were generally higher than those entering the upstream limit of the Study Area (W024 at RM 16) under all flow conditions. The highest contaminants concentrations in surface water within the Site were found near known sources of these either in sediments or upland (e.g., stormwater outfalls). At RM 2 (W001, W002,

W025) and Multnomah Channel (W027), the downstream end of the Study Area, concentrations of total PCBs, dioxin/furans, DDx, BEHP, chlordanes, aldrin and copper in surface water reflect discharge of these contaminants to the Columbia River.

1.2.3.3 Groundwater

Figure 1.2-20 and **Figure 1.2-21** (inset of the Doane Lake area) show the nature and extent of known contaminated groundwater plumes currently or have the potential of discharging to the river. Cleanup of contaminated groundwater is being managed by DEQ under an MOU with EPA. The following provides a discussion of the groundwater plumes presented in **Figures 1.2-20** and **1.2-217**:

East Side of Willamette River

RM 2

Evraz Oregon Steel Mill –Contaminants are manganese and arsenic. Arsenic concentrations in beach monitoring wells exceed MCLs.

RM 3.5

Time Oil – Contaminants are pentachlorophenol, arsenic, gasoline- and diesel-range hydrocarbons. A pump and treat system is operating to prevent migration of the pentachlorophenol plume from reaching the river via a stormwater outfall and prevent offsite migration to the Premier Edible Oils property. There are three TPH plumes identified at this site; the northern plume is not discharging to the river, the middle plume is discharging to the river, but arsenic is the only contaminant for which concentrations exceed SLVs. The southern upland plume migrates a short distance onto the Premier Edible Oils property and is not discharging to the river.

Premier Edible Oil – Contaminants are TPH (diesel-range hydrocarbons), manganese, and arsenic.

Schnitzer Steel Industries – A halogenated VOC plume is known to be discharging to the river. Contaminants include cis-1,2-dichloroethene (cis-1,2-DCE), tetrachloroethene (PCE), and trichloroethene (TCE).

RM 4.5

NW Pipe – A halogenated VOC plume is known to discharge to the river. Contaminants include PCE, TCE, and vinyl chloride.

Terminal 4 Slip 3 – Contaminants include TPH (diesel-range hydrocarbons).

RM 6

McCormick & Baxter Creosote Co. – Contaminants include pentachlorophenol (PCP), PAHs, arsenic, chromium, copper, and zinc. An upland groundwater barrier wall system and in-river sediment cap has been installed that isolates contaminated

groundwater from the river. A 5-Year Review completed in 2011 by EPA and DEQ determined constructed remedies are protective to human health and the environment.

RM 11

Tarr Oil – A halogenated VOC plume not known to be releasing to the river. Contaminants include cis-1,2-DCE, PCE, TCE, and vinyl chloride

West Side of Willamette River

RM 4

Kinder Morgan Linnton Bulk Terminal – A TPH plume is located onsite and has released to the river. Contaminants include LNAPL, diesel-range hydrocarbons, residual-range hydrocarbons, and gasoline-range hydrocarbons. A sheet-pile wall has been constructed to prevent LNAPL migration to the river.

RM 5

BP Arco Bulk Terminal – A TPH plume has discharged to the river. Contaminants include TPH (gasoline-range and diesel-range hydrocarbons) and LNAPL, and the plume extends under the adjacent downstream property. A sheet-pile wall with groundwater hydraulic control system is in place. A groundwater pump and treat system and LNAPL recovery system is in use.

Exxon Mobil Bulk Terminal – A TPH plume has discharged to the river. Contaminants include gasoline- and diesel-range hydrocarbons. A bentonite wall has been constructed along the riverbank for the majority of the site. A groundwater pump and treat system is in place and operating at the downstream end of the site where the cutoff wall is absent. Treatment of the source areas via air sparging is ongoing.

RM 5.5

Foss Maritime/Brix Marine – TPH releases from underground storage tanks (USTs) have been identified onsite. Contaminants include gasoline- and diesel-range hydrocarbons.

RM 6

NW Natural/Gasco – Groundwater plumes associated with historical MGP waste are known to be discharging to the river. Contaminants include PAHs, SVOCs, VOCs, gasoline- range hydrocarbons, diesel- range hydrocarbons, residual-range hydrocarbons, cyanide, sulfide and carbon disulfide, aluminum, ammonia, iron and metals. A hydraulic control pump and treatment system has been constructed at the riverbank and is currently being tested.

RM 6 and RM 7

Siltronic – A VOC plume as well as groundwater plumes associated with historical MGP waste and pesticide plumes from Rhone Poulenc are known to discharge to the river. Contaminants include petroleum-related and chlorinated VOCs (benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,1-dichloroethene,

cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride), PAHs, gasoline- range, diesel-range, and residual-range hydrocarbons, cyanide, metals, Silvex, and dichlorprop. In-situ bioremediation and treatment with zero-valent iron has been implemented to reduce halogenated VOC concentrations discharging to the river. The NW Natural hydraulic control pump and treatment system extends to the northern portion of the Siltronic site is expected to control the TCE plume in addition to the Gasco MGP plume.

RM 7

Rhone Poulenc – Known releases of organochlorine insecticides and herbicides, including PCP, 2,4-DP, Bromoxynil, 4(2,4-dichlorophenoxy)butyric acid (2,4-DB), 2-methyl-4-chlorophenoxyacetic (MCPA), methylchlorophenoxypropionic acid (MCP), 4-(4-chloro-2-methylphenoxy)butanoic acid (MCPB), 2,4,5-trichlorophenoxyacetic acid [2,4,5-T], 2,4-dichlorophenoxyacetic acid (2,4-D), DDT, Endrin, Heptachlor, sodium chlorate, sodium arsenate, 2,4,5-TP (Silvex), aldrin, dieldrin, chlordanes, and dichlorprop are known to discharge to the river. Additional contaminants include 1,2-dichlorobenzene, chlorobenzene, 1,3-dichlorobenzene, benzene, DDx, and dioxins/furans.

Kinder Morgan Pump Station – A TPH plume has been identified at the pump station. The extent of the plume is currently unknown.

Arkema – A DDT and halogenated VOC plume is located on the northern section of the property and discharges to the river. On the southern end of the property, several plumes containing DDT, chlorobenzene, PCE, chloroform, hexavalent chromium, perchlorate, chlorinated furans, and salts also discharge to the river. Investigation of the VOC plume is ongoing. A barrier wall and groundwater pump and treat system is being constructed to manage the groundwater plumes on the southern end of the property.

RM 9

Kinder Morgan Willbridge Bulk Terminal – A TPH plume is not known to be currently discharging to the river. Contaminants include gasoline- range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and arsenic. Evaluation of the plume is ongoing.

Chevron and Unocal Willbridge Bulk Terminal – A TPH plume located onsite has discharged to the river. Contaminants include LNAPL, gasoline- range hydrocarbons, diesel- range hydrocarbons, residual-range hydrocarbons, and arsenic. Nineteen control measures have been implemented at the site between the early 1970s and 2010 to address the potential migration of impacted groundwater to the Willamette River. Recent high groundwater conditions have identified some concerns with the adequacy of the LNAPL containment system; additional characterization is in progress, and it is expected that modifications to the LNAPL containment system will be proposed.

Chevron Asphalt Plant – Free product consisting of relatively immobile asphalt-related petroleum has been noted on site. Contaminants include TPH (diesel-range and gasoline-range hydrocarbons), arsenic, BTEX and naphthalene. DEQ has concluded that the plume is not discharging to the river.

Gunderson – There are two known groundwater plumes at the Gunderson property. A chlorinated VOC plume (1,1-DCE, 1,1,1-trichloroethane [1,1,1-TCA], PCE, TCE and vinyl chloride), and PAH plume located between the Equilon (Shell Terminal) pipeline gasoline release and the Equilon dock at Gunderson. An AS/SVE and a pump and treat system were operating for the VOC plume. DEQ approved the shut-down of these systems and a schedule of expanded groundwater monitoring. The PAH plume was determined by DEQ to not be discharging to the river

Christensen Oil – A TPH (Stoddard solvent) plume is located onsite. The plume extent is not known to currently discharge to the river since a dual phase extraction and treatment system is currently operating to control migration of the plume. Evaluation of the control is ongoing.

Univar – A VOC plume is located onsite. Contaminants include 1,1-DCA, 1,1-DCE, cis-1,2-DCE, methylene chloride, PCE, toluene, 1,1,1-TCA, TCE, vinyl chloride, and xylenes, . The plume does not extend to the river. Soil vapor extraction and pump and treat systems have been implemented as interim corrective measures.

Galvanizers Inc. – A zinc plume located at this site is not known to currently discharge to the river. The plume may have infiltrated the storm water system that discharged to the river; however, that system has been diverted to the City Big Pipe project.

RM 10

Sulzer Pump – TPH, PAH, and VOC plumes from UST and waste oil UST releases exists at this site.

RM 11.5

Centennial Mills – A TPH (diesel-range hydrocarbons) plume is located at this site. The plume is not known to discharge to the river, but may be infiltrating the Tanner Creek sewer line near the river.

1.2.3.4 River Banks

Figure 1.2-7 shows the nature and extent of known or suspected contaminated river banks within the Study Area. Identification of contaminated banks is being managed by DEQ under an MOU with EPA. The following provides a discussion of the known contaminated banks:

East Side of Willamette River

RM 2

Evraz Oregon Steel Mill – Contamination in the riverbank is PCBs.

RM 3.5

Schnitzer Steel Industries – Results of soils samples collected under the docks along the south shore of the International Slip indicate that contaminants are PCBs and dioxins.

RM 5.5

MarCom South – Further investigation of the nature and extent of contamination in the bank was conducted in 2012. Contaminants are arsenic, cadmium, chromium, copper, zinc, and PAHs.

RM 7

Willamette Cove - Riverbank contaminants are PCBs, dioxins/furans, lead, mercury, nickel, copper, and PAHs.

RM 8.5

Swan Island Shipyard – Recent sampling results for OU1 indicate that contaminants include arsenic, cadmium, chromium, copper, lead, mercury, zinc, PAHs, PCBs, and tributyltin. Contaminants in river bank soils in OU2 include metals (arsenic, cadmium, copper, lead, and zinc), PAHs, PCBs, and tributyltin. Work at OU5 indicated metals (arsenic, copper, lead, and zinc), PAHs, and PCBs in river bank soils.

West Side of Willamette River

RM 4

Kinder Morgan Linnton Bulk Terminal – Contaminants are petroleum constituents (BTEXs and PAHs) and metals.

RM 6

NW Natural/Gasco – Contamination associated with historical MGP waste are known to be located in the river bank. Contaminants include PAHs, gasoline- range hydrocarbons, diesel- range hydrocarbons, residual-range hydrocarbons, cyanide, and metals.

RM 6 and RM 7

Siltronic – Contamination associated with historical MGP waste and pesticide and herbicide releases from Rhone Poulenc and Arkema are known to be located in the river bank. Contaminants include PAHs, gasoline- range hydrocarbons, diesel- range hydrocarbons, residual-range hydrocarbons, cyanide, metals, PCP, 2,4-DP, Bromoxynil, 2,4-DB, MCPA, MCPP, MCPB, 2,4-T, 2,4-D, DDT, Endrin, Heptachlor, sodium chlorate, sodium arsenate, 2,4,5-TP, 2,4,5-T, aldrin, dieldrin, and chlordanes.

RM 7

Arkema –Riverbank contaminants include DDT, dioxin/furans, PCBs chromium and lead.

RM 9

Gunderson –Contaminants include lead, nickel, zinc, and PCBs.

1.2.4 Contaminant Fate and Transport

Most of the sediment contamination at the Site is associated with known or suspected historical sources and practices. Ongoing contaminated groundwater plumes, river bank soils, and upstream surface water. The distribution contaminants in sediments in several nearshore areas appears to reflect more significant historical lateral inputs. The spatial correlation between PCBs in aquatic organisms and sediments indicate that contamination in bottom sediments are an ongoing source of persistent bioaccumulative contaminants such as PCBs, DDX and dioxin/furans contamination to biota.

The major internal fate and transport processes are:

- Erosion from the sediment bed
- Deposition to the sediment bed
- Dissolved flux from the sediment bed (porewater exchange)
- Groundwater advection
- Degradation (for some contaminants)
- Volatilization
- Downstream transport of either particulate-bound or dissolved phase contaminants

These processes interact to create complex patterns of contaminant redistribution that vary over space, time, and by contaminant. A discussion of fate and transport modeling for different classes of contaminants, which estimated the magnitude of various processes within the Study Area, is presented in the RI. **Figures 1.2-22a through 1.2-22c** provides a visual summary of currently known or suspected contaminant source loads within and exiting from the Site for three representative contaminants: total PCBs, benzo(a)pyrene, and DDE.

Patterns of contamination in bedded surface sediment suggest some redistribution of contaminants over time from past source areas, but this is limited by re-burial of much of the source area contamination (as indicated by higher subsurface sediment

concentrations in these areas). Periodic erosion may temporarily expose buried contamination.

Groundwater plume advection and release has been observed in several areas along with dissolved phase flux from surface sediments to the water column.

Based on results of surface water data collected during the RI, resuspension and/or dissolved phase flux from the sediment bed are contributing to contaminant concentrations in surface water, particularly in quiescent areas where surface water mixing and dilution is minimal. Loading estimates presented in **Figures 1.2-22a through 1.2-22c** are consistent with this concept, indicating the mass flux of contaminants exiting the downstream end of the Study Area in surface water (either directly to the Columbia River or via Multnomah Channel) is greater than the flux entering the Study Area. Contaminant concentrations in loads entering the Study Area from adjacent upland sources and pathways (such as stormwater) are generally greater than concentrations in the upstream loads (upriver surface water and sediments). Stormwater input is the most important current source pathway within the Study Area for many contaminants, including PCBs and DDx.

Finally, empirical tissue contaminant data and food web modeling indicate that persistent contaminants (particularly PCBs and dioxin/furans) in sediments and surface water bioaccumulate in aquatic species tissue.

The CSM integrates the information gathered to date to provide a coherent hypothesis of the Site fate and transport. **Figure 1.2-23** provides a general overall visual summary of this hypothesis, including contaminant interactions with human and ecological receptors.

1.2.5 Baseline Risk Assessment

This section presents a summary of the results of the baseline human health risk assessment (BHHRA) and BERA completed as part of the RI conducted under CERCLA. These assessments are summarized in Sections 8 and 9, respectively, of the RI, and in their entirety in Appendices F and Appendix G

1.2.5.1 Baseline Human Health Risk Assessment

The BHHRA presented an analysis of potential for effects associated with both current and potential future human exposures at Portland Harbor and followed an overall process based on EPA guidance and numerous agreements with EPA, DEQ, Oregon Health Authority (OHA, formerly the Department of Human Services), and Native American Tribes. Potential exposure to contaminants found in environmental media and biota was evaluated for various occupational and recreational uses of the river, as well as recreational, subsistence, and traditional and ceremonial tribal consumption of fish caught within the Portland Harbor site. Additionally, because of the persistent and

bioaccumulative nature of many of the contaminants found in sediment, infant consumption of human breast milk was also quantitatively evaluated

Consistent with EPA policy, the BHHRA evaluated a reasonable maximum exposure (RME). In addition, estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. **Figure 1.2-24** presents the conceptual site model for the BHHRA.

The major findings of the BHHRA are:

- Estimated cancer risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment and surface water. Risks and noncancer hazards from fish and shellfish consumption exceed the EPA point of departure for cancer risk of 1×10^{-4} and target hazard index (HI) of 1 when evaluated on a harbor-wide basis, and when evaluated on the smaller spatial scale by river mile.
- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4×10^{-3} and 1×10^{-2} for recreational and subsistence fishers, respectively. Evaluated on a river mile scale, it is only at RM 5 that the risk from consumption of resident fish is less than 1×10^{-4} .
- Noncancer hazard estimates for consumption of resident fish species are greater than 1 at all river miles. Based on a harbor-wide evaluation of noncancer risk, the estimated RME HI is 300 and 1,000 for recreational and subsistence fisher, respectively. The highest hazard estimates are at RM 4, RM 7, RM 11, and in Swan Island Lagoon. The highest noncancer hazards are associated with nursing infants of mothers, who consume resident fish from Portland Harbor. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME HI for tribal consumers of migratory and resident fish is 600 assuming fillet-only consumption, and 800 assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers, who consume fish, are 8,000 and 9,000 respectively, assuming maternal consumption of fillet or whole-body fish.
- PCBs are the primary contributor to risk from fish consumption harbor-wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates, particularly at RM 6 and 7. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The greatest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from Portland Harbor. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it is not clear to what degree contamination in Portland Harbor contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific disease, and the cancer estimates represent upper-bound values, and the EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.

1.2.5.2 Baseline Ecological Risk Assessment

The BERA presents an evaluation of risks to aquatic and aquatic-dependent species within the Study Area in the absence of any actions to control or mitigate contaminant releases. The overall process used for the BERA was based on the guidance provided in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final* (EPA 1997c) and followed the approach documented in numerous interim deliverables as well as discussions, directives, and agreements with the LWG, EPA and its federal, state, and tribal partners. **Figure 1.2-25** presents the conceptual cite model for the BERA.

The following presents the primary conclusions of the BERA.

- In total, 93 contaminants (as individual contaminants, sums, or totals)² with HQ ≥ 1.0 pose potentially unacceptable ecological risk. Differences in the specific toxicity reference values (TRVs) used in different lines of evidence (LOEs) for total PCBs (e.g., total PCBs versus specific Aroclor mixtures), total DDx, and total PAHs, all of which describe individual contaminants or a group of multiple but related individual chemical compounds, can result in different counts of the number of contaminants posing potentially unacceptable risk. The list of contaminants posing potentially unacceptable risks can be condensed if individual PCB, DDx and PAH compounds or groups are condensed into three comprehensive groups: total PCBs, total DDx, and total PAHs. Doing so reduces the number of contaminants with HQ ≥ 1.0 posing potentially unacceptable risks to 66.
- Risks to benthic invertebrates are clustered in 17 benthic AOCs.

² The five chemicals or chemical groups with concentrations that exceeded only the sediment probable effects concentration (PEC) and/or probable effects level (PEL) (i.e., chemicals that were not identified as COPCs for other benthic invertebrate LOEs: Aroclor 1254, chlordane [cis and trans], gamma-hexachlorocyclohexane [HCH] [Lindane], heptachlor epoxide, and total chlordane), ammonia and sulfide (which are conventional parameters), and residual-range hydrocarbons that had concentrations that exceeded only the total petroleum hydrocarbons [TPH] SQGs) are not included in this count.

- Sediment and TZW samples with the highest HQs for many contaminants also tend to be clustered in areas with the greatest benthic invertebrate toxicity.
- The COPCs in sediment that are most commonly spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs and DDx compounds.
- Not all COPCs posing potentially unacceptable risk have equal ecological significance. The most ecologically significant COPCs are PCBs, PAHs, dioxins and furans, and DDT and its metabolites.
- The list of ecologically significant COPCs is not intended to suggest that other contaminants in the Study Area do not also present potentially unacceptable risk.
- The contaminants identified as posing potentially unacceptable risk in the largest numbers of LOEs are (in decreasing frequency of occurrence) total PCBs, copper, total DDx, lead, tributyltin (TBT), zinc, total toxic equivalent (TEQ), PCB TEQ, benzo(a)pyrene, cadmium, 4,4'-DDT, dioxin/furan TEQ, bis(2-ethylhexyl) phthalate, naphthalene, and benzo(a)anthracene. The remaining 78 contaminants posing potentially unacceptable risk were identified as posing potentially unacceptable risk by three or fewer LOEs.
- Of the three groups of contaminants (i.e., total PAHs, total PCBs, total DDx) with the greatest areal extent of HQs ≥ 1.0 in the Study Area, PAH and DDx risks are largely limited to benthic invertebrates and other sediment-associated receptors. PCBs tend to pose their largest ecological risks to mammals and birds.
- The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as total TEQ, poses the potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey. The PCB TEQ fraction of the total TEQ is responsible for the majority of total TEQ exposure, but the total dioxin/furan TEQ fraction also exceeds its TRV in some locations of the Study Area.

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